

JUNE 11, 1990

CHEMICAL & ENGINEERING

# NEWS

## SCIENCE EDUCATION

Enabling the general public;  
filling the science pipeline

Page 27

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## Chemical & Engineering News

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## LETTERS

### Animals in research

SIR: The article "Animals in Research" (C&EN, May 7, page 9) did what anyone exploiting the helplessness of other living beings must do: resort to distortions in order to avoid facing truths that are inevitably discomfiting and occasionally life-changing.

You asked, "Do animals have rights?" Your insightful answer: "Every active biomedical researcher interviewed for this article says 'no.'" But perhaps you might have asked Donald Barnes, a former career vivisector who now heads the National Anti-Vivisection Society. Or Michael A. Fox, who wrote a book called "The Case for Animal Experimentation," and upon further reflection had the courage to denounce his book and become a vocal animal rights advocate. They and thousands of others have concluded that humans aren't the only species deserving to live without purposely inflicted suffering; that "First, do no harm" should apply to all beings capable of feeling pleasure and pain.

Finally, the article insinuated that animal rights activists have "invented" utilitarian arguments against animal experiments because people wouldn't otherwise be persuaded. In fact, we have no need to invent arguments, as millions of humans have already become victims of a health care system that ignores the poor and emphasizes the search for dubious "cures" despite the fact that heart disease, stroke, adult-onset diabetes, and 30 to 60% of cancer causes are preventable. According to the *New York Times*, Louis Sullivan, Secretary of Health & Human Services and animal rights opponent, has stated, "More healthful living, which includes quitting smoking, using seat belts, reducing violence, and eating more nutritiously, is the key to improving health. That is clear in light of findings that more than half the causes of premature death are related to patterns of life."

Jill Leonard

People for the Ethical Treatment of Animals

SIR: The article on the animal rights issue was an excellent article in informing scientists of the increasing problems presented by the so-called animal rights activists. As a research chemist for a major agricultural chemical company that must use animal testing in registering or reregistering products, we are very much concerned with the explosive growth of these militant groups and the problems they present with the advancement of scientific knowledge.

As an avid hunter I have had many encounters with these animal rights activists and I feel that my experiences and observations will be of benefit to those

scientists who are just getting their feet wet in dealing with these people. These people are fanatically dedicated to their crusade; no amount of hand-wringing or wishful thinking will make them go away. No amount of logical thinking supported with scientific facts will divert them from their moralistic and emotional arguments. Any person who thinks that he can make a compromise with these people is a fool. Today's compromise is the basis for tomorrow's negotiations on additional compromises. To the animal rights activists, the concept of animal rights is an all or nothing proposition. There is no middle ground. The animal rights groups are very well financed and actively recruit celebrities as their qualified spokespersons.

The general public is uncommitted to the animal rights movement. They will listen to logical presentations supported with scientific facts. We scientists must do a better job of educating the public to the benefits of the use of animals in research. In doing so, they will see the animal rights activists for the narrow-minded zealots that they are.

The next time you read about or hear a news item that projects hunters in a negative image, please remember that the sources are the same as those who are running smear campaigns to end the use of animal research. Hunters, trappers, and scientists may make for strange bedfellows, but we all are in the same boat when dealing with these narrow-minded people. Perhaps an effort by all of us to support one another will greatly aid in educating the public of the narrow-minded militant stance posed by these activists.

John Vargo

Greensboro, N.C.

SIR: The evident hostility toward animal rights advocates displayed in the recent article on the use of animals in research was disappointing but not surprising. The American Medical Association launched last year a campaign to dis-

Continued on page 50

### Corrections

• May 21, page 21: The 50-year history of the Chemical Marketing Research Association was prepared by William E. Marklewitz, a former CMRA president, not by Henry F. Whalen Jr.

• April 23, page 3: The sentence in the second paragraph of the letter on the toxicity of chlorofluorocarbons should read, "More recently, a CFC ... was shown to act as a cocarcinogen," not carcinogen.

# Winds of Revolution Sweep Through Science Education

Science education, including chemistry, is on the verge of major restructurings as responses grow to personnel pipeline crisis and public literacy issues

James Krieger, C&EN Washington

When social historians of the future look back on 1990, they may mark it as a pivotal year in the reform of science education in the U.S. True, expressions of concern have been filling the air for at least the past five years. And a number of programs taking action to address science education needs have come into being in the past year or two. But those concerns and programs are now building into something of a movement for reform that, if it continues to broaden and deepen, could completely change the face of science education in the U.S. from cradle to college.

Among the factors intensifying the situation are two major issues that have come together and reinforced each other: on the one hand, science education and science literacy for the general public, and on the other, filling the science personnel pipeline in the relatively near future. Exacerbating these issues are the spreading concerns about shoddy education in general and its impact on U.S. competitiveness.

The public education and pipeline issues run parallel, sometimes merg-

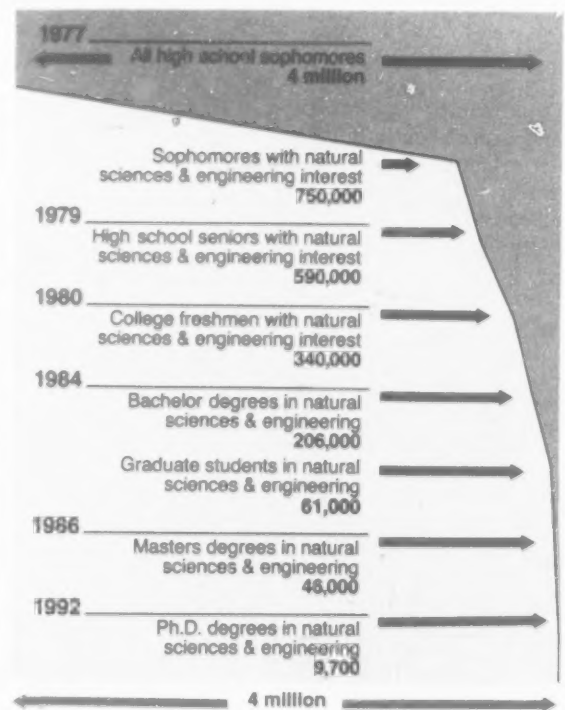
ing to become one, sometimes exhibiting separate aspects. Now common to both is an overarching realization that solutions must be comprehensive. Piecemeal approaches help but aren't sufficiently encompassing.

Chemistry is certainly caught up in this maelstrom of concern that is sweeping through science. Indeed, both the public education and pipeline themes permeated the program in Boston at the recent national meeting of the American Chemical Society.

"Wouldn't it be great," said one speaker in Boston, "if this ACS meeting could fire the shot heard round the world for the education of America's young people."

The Boston ACS meeting is not likely to gain that distinction. A strong case can be made that it already belongs to the 1983 "Nation-at-Risk" report by a Department of Education panel that stated "the educational foundations of our society are presently being eroded by a rising tide of mediocrity that threatens our very future as a nation and a people." Indeed, a recent editorial in the *Washington Post* noted that reports lamenting the perilous state of this country's scientific literacy now number above 300.

The science pipeline:  
Constricting to a trickle of Ph.D.s



Source: National Science Foundation

Nevertheless, the ACS meeting can lay claim to an effort of consciousness-raising in the chemical community on an unprecedented scale and perhaps to a sharp escalation in the energy level of that community in pressing for change. The energy will have to be sustained. No one believes there is any sort of short-term solution available for something that has, by all accounts, gone terribly awry.

### Variety of groups working for educational change

The activity generated over recent years has been taking place across a broad front. In just the past 16 months, notable efforts have come from scientific societies, from industry, and from government. Among them:

- In February 1989, the American Association for the Advancement of Science released a report "Science for All Americans" as the first phase of its Project 2061 (C&EN, March 13, 1989, page 22). Project 2061 (named for the next appearance of Comet Halley, which will be seen by children in school today) is a long-term effort for achieving science literacy aimed at precollege education. "Science for All Americans" focused on defining the substance of science literacy. Phase II, now under way, is focused on development of new curriculum models and reform of teacher education, teaching materials and technologies, and other areas.

- In April 1989, Sigma Xi, the scientific research society, reported on a conference of a National Advisory Group it had convened in January. The charges to the advisory group were to explore the nature and quality of undergraduate education in science, mathematics, and engineering, and to identify the significant topics and issues that should be addressed in charting policy for undergraduate education in science, mathematics, and engineering.

- Last year, a Union Carbide corporate task force on education spent six months studying public education in the U.S. to determine the implications for Union Carbide and to recommend a role for the corporation in addressing national education issues. The task force's report, "Undereducated, Uncompetitive U.S.A.," recommended Carbide support and initiate programs designed to bring down barriers to school reform and to stimulate change, with efforts directed both externally to the general public and internally to the company's employees.

- Last November, ACS held a briefing for Congress on a newly formulated white paper called "Education Policies for National Survival" (C&EN, Nov. 27, 1989, page 54). The white paper was a synthesis of more detailed policies developed by ACS that were concentrated into one succinct form by a subcommittee of the Society Committee on Education. It offered some 70 recommendations for actions that would address all levels from kindergarten through university and graduate training and continuing education of teachers and scientists.

- Early last month, AAAS dropped the other shoe with its report, "The Liberal Art of Science" (C&EN, May 14, page 4). A college-level counterpart to "Science for All Americans," the new report urges colleges and

universities to restructure their degree programs so that all graduates acquire a broad understanding of science and its impacts. Science majors and nonmajors alike, the report says, should be taught science as a liberal art.

- Also early last month, the National Science Foundation added to its existing science education efforts, soliciting proposals under a program for statewide systemic initiatives in science, mathematics, and engineering education (C&EN, May 14, page 4). The program seeks to enlist the political leadership of the state, the business leadership, the civic leadership, universities and colleges, and the public school systems to bring about systemic change statewide.

- And late last month, the Department of Energy weighed in with release of a report detailing the results of a Math/Science Education Action Conference it had convened last October at Lawrence Hall of Science in Berkeley, Calif. (C&EN, May 28, page 8). Accompanying the report was a delineation of science education initiatives at DOE laboratories, along with memoranda of understanding with various organizations such as the National Aeronautics & Space Administration and the Appalachian Regional Commission, all focused on science, engineering, and mathematics education.

Judging from current anxiety over where the future supply of scientists will be coming from—how the pipeline will be filled—such actions come none too soon. In fact, they may already be too late to alleviate shortages in the near term.

"As we look down the road for the next 10 years, we see that the retirement curve is going to go up very dramatically," says Paul G. Gassman, University of Minnesota chemistry professor and president of ACS. "At the same time, the production curve is going to go down very dramatically. These are going to cross rather drastically. I think the collision is going to spell disaster."

Gassman, along with Betty M. Vetter, executive director of the Commission on Professionals in Science and Technology (formerly the Scientific Manpower Commission), and Bassam Z. Shakhshiri, then assistant director for science and engineering education at NSF, wrestled with the pipeline issue at the presidential plenary session at the Boston ACS meeting. Gassman chose the issue as the subject of the session, he says, because of "my very great concern that as we approach the 21st century we will not have sufficient scientists to maintain our status as a strong industrial nation, and this will very dramatically impact on our overall economy, and certainly on our ability to train future scientists."

For chemistry, the crunch will not be long in coming. Colleges and universities today, Gassman points out, are generating about 200 new positions per year for chemistry faculty because of retirements. Since the schools are about one year behind in filling the openings, there are about 400 at any given time. In five years, Gassman says, there will be 300 openings generated per year. In 10 years, there will be 500. In 12 years, openings will increase to very close to 600 per year. That is just the academic demand for Ph.D. chemists.

The contents of the pipeline that will be supplying the chemists to meet that demand as well as an antici-



Shakhshiri (left to right), Gassman, and Vetter express concern over the ebb in number of students preparing to enter the personnel pipeline

Photos by C&EN's James Krueger

pated increase in demand from industry are very well known. "We can tell you plus-or-minus 50 how many Ph.D. chemists will graduate every year to the year 2000," Gassman says, "and we know that we will not begin to meet the numbers that we will need."

Overall figures give the impression that production of Ph.D. chemists has been fairly constant. But, Gassman points out, there are some very misleading data hidden there. For example, the number of foreign nationals in the group receiving chemistry Ph.D. degrees has increased sharply and continues to rise. During the same period, the number of U.S.-born students receiving chemistry Ph.D.s has decreased and recently has dropped off very rapidly.

Everyone who is going to get a Ph.D. degree in chemistry in the 1990s is either in undergraduate school or graduate school right now, Gassman notes. Thus, in the mid-1990s, 125 U.S.-born Ph.D. chemists will graduate per year.

And fewer and fewer have any interest in academic jobs. In 1970, the National Research Council surveyed all graduating Ph.D.s in chemistry and found that 18.5%—411 individuals at that time—wanted academic jobs. The same survey 15 years later (it is conducted at five-year intervals) found only 8% of graduating Ph.D.s in chemistry wanted academic jobs. That percentage equates with just 147 individuals.

One reason for the drop, Gassman says, is that there is a perception among students that the life of a professor is no longer so attractive as it was at one time. For instance, students see their advisers struggling for grant funds. "Today one writes roughly three times as many proposals to get a grant, on average, as one did 10 years ago," Gassman explains. "This has a very dramatic impact on the attitudes of students and on their tendencies to want to go on and teach the next generation."

Gassman points out that until now, there has been in

the U.S. a pretty good balance between supply and demand of scientists, and it has been possible for universities to fill academic positions with reasonably qualified people. Part of the problem Gassman foresees is that "when supply and demand get totally out of kilter, we will have hired into our universities, when they can be found, people who are less qualified. They will train the next generation. This is just a long-term effect, which takes several generations to cure."

Hence, the situation is not one for which there is any kind of quick fix. The pipeline for chemistry, Gassman points out, is now an 11-year pipeline, from the start of undergraduate school to the receipt of a Ph.D. Even if it were possible to change the attitudes of incoming freshmen, it would be 11 years before the impact would be felt. But Gassman doesn't believe there are individuals coming out of high school who are adequately trained in math and science, and adequately motivated toward science to be able to have a major impact on supply 11 years down the road.

"From my own perspective," Gassman says, "I think it will take a minor miracle to graduate as many U.S.-born Ph.D. chemists in the year 2010 as we did in 1985."

As for drawing on foreign scientists as a way around the problem, that may not be so easy in the future as it might appear. The foreign competition is getting much better, Gassman says, citing Taiwan as an example. One of the major sources of graduate students in chemistry in the U.S., he explains, has been Taiwan, but today the number of applicants from Taiwan is dropping off dramatically. The reason, he says, is that "Taiwan has built very fine universities, it has hired faculty from throughout the world to staff those universities, and they are keeping their students at home."

Nor may there be much solace in recalling how 30 years or so ago, the U.S. rallied in response to the orbiting Sputnik satellite to increase the flow of talent into

## Special Report

careers in science, mathematics, and engineering. NSF had a lot to do with that increase. Says Shakhshiri, "I think the situation we face now is by far more critical and more consequential than what we faced back then."

It is so for several reasons, Shakhshiri says. One is the tremendous change in scale of the problem that has occurred in the past 30 years as the population of the U.S. has increased by 50 million people. That change, he says, means there are more students to teach and there is a greater need for qualified teachers at all educational levels, not only precollege and undergraduate levels but also the graduate level. Moreover, there is the pipeline problem with a decreased flow of talent going into areas of teaching science, mathematics, and engineering. And third, the scientific and technological nature of society is much more advanced, requiring attention be paid to the nonspecialist.

### Fewer students intensify the problem

Overall demographics also provide little reassurance. There are fewer college-age students today than there were in the mid- to late 1970s, explains Vetter, and the size of that population will continue downward through the mid-1990s. Not only is there a 25% drop in the size of the college freshman population, she adds, but the racial and ethnic characteristics of those potential freshmen also are changing significantly. Today's elementary children include more black, Hispanic, Native American, and Asian than is true for the American population as a whole, so students of college age must increasingly be drawn from minority groups.

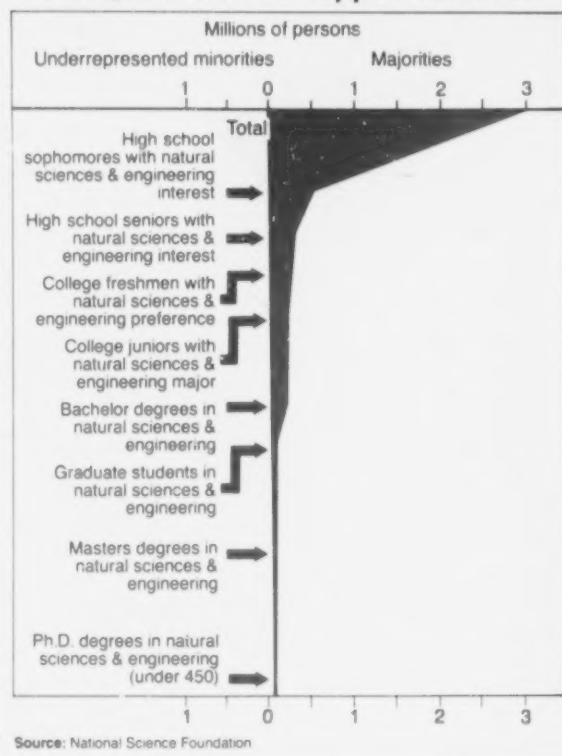
In addition to the drop in college-age students, the white male population from which scientists traditionally have been self-selected is a shrinking portion of the college-age population, Vetter points out. Within the overall contracting population, students have been indicating less interest each year since 1982 in majoring in any of the natural science or engineering fields.

Moreover, Vetter says, each year since 1982, fewer and fewer merit scholars have chosen these fields. The percentage of merit scholars choosing science has dropped from 23% to 19% just since 1982, and the percentage choosing engineering has dropped from 26% to 20% in less than five years. "So," Vetter says, "we have a quality problem as well as a quantity problem."

That's at the undergraduate level. Like Gassman, Vetter also notes the increasing number of foreign citizens at the graduate level. There were 1971 Ph.D.s in chemistry awarded in 1989, she points out, and of these 28% were awarded to foreign students. Of the American students, the percentage of men earning the degrees was down 11% in one year. The number of women earning them was up 11%—though from a small base—for a net combined 6% drop. Only 8% of the Americans gaining Ph.D.s in 1989, Vetter says, were black, Hispanic, Native American, or Asian. This was the same percentage as in 1988, although these groups make up about 30% of the U.S. population.

"If we need to increase the numbers," Vetter says, "and there appears to most of us to be little doubt that we do, then our very best source will be women and, to

### The science pipeline: Underrepresented minorities are one untapped source...



a somewhat lesser extent because there are fewer, minority males." But, Vetter adds, there are many barriers, both apparent and hidden, to increasing the interest and participation of these underutilized groups.

Salaries paid to women, for example, are lower than those paid to men, even at the first position after the doctorate, Vetter says. Since women progress more slowly in terms of salary increases and are less likely to be moved into management positions, the differential increases with years of experience. The salary gap between men and women for a typical doctoral scientist averages about \$9000 per year. "Over a lifetime," says Vetter, "it is easy to see why women should be discouraged by this. They are, after all, charged the same fees and tuition as their male classmates."

If there is to be an increase in production of scientists and engineers to meet expected needs for the coming decade and the start of the next century, Vetter says, steps must be taken now to supplement the potential supply. There are just two choices, she maintains: Assume there will be enough if nothing is done; or assume that there will not be enough unless something is done.

"Personally, I'd prefer to plan for the latter scenario," Vetter says. "If this turns out to be wrong, there are many productive ways to utilize doctoral scientists. But if we make the first choice, there are no later options in case we turn out to be wrong."

Narrowing the focus to a single school adds a more personal touch to the disciplinewide situation. It doesn't, however, make it any more hopeful, at least in experiences such as those at Purdue University. Kay A. Conner, undergraduate adviser to chemistry majors and to science majors in general at Purdue, has made an analysis of the freshman class of 1987. There were 97 entering freshman chemistry majors. In the fall of 1989, only 15 of the 97 were left as chemistry majors. "I was amazed," says Conner, who then decided to find out where they had gone.

Of the remaining 82, 20 had dropped out of school, and 62 had chosen another major. An informal poll, Conner says, indicated that the management school would have been the first choice for most of them, followed by the engineering school. But those schools were difficult to get into, taking students according to space available.

So, a large number of them, 16, went into liberal arts. Nine went into biology, eight into health sciences, and three each into management, agriculture, consumer and family science, other science majors, and technology. Conner summarizes these data by saying almost all of the 62 chose an easier major—meaning they could get by with taking less math, less physics, less chemistry, and not having to work as hard. The 15 chemistry majors, Conner says, were the better students.

Chemistry did recruit some students from other areas, bringing the class to 37 students. Six came from chemical engineering, five from biology, three from other engineering, two from physics, one from math, and five were transfer students who generally were majoring in chemistry at the other school.

And 1987 was not an unusual year, Conner says. From 1985 to 1988, 379 started in chemistry; 74 stayed in chemistry.

This past school year for the first time, Conner says, she put together a profile with a wide variety of information about incoming freshmen. The most important thing she found, she says, was information regarding the first-year math course: Of 95 chemistry majors, 40% were starting out in remedial math.

The first-year math requirement is based on an entry-level algebra/trigonometry test—a "simple" test, Conner says, "and 40% of our incoming school of science students that would like to major in chemistry cannot pass this test." This is despite the fact, she says, that 100% of them had had at least three semesters of algebra with high grades, and most of them had also had at least a semester of trigonometry.

### Student anecdotes paint a not-too-pleasant picture

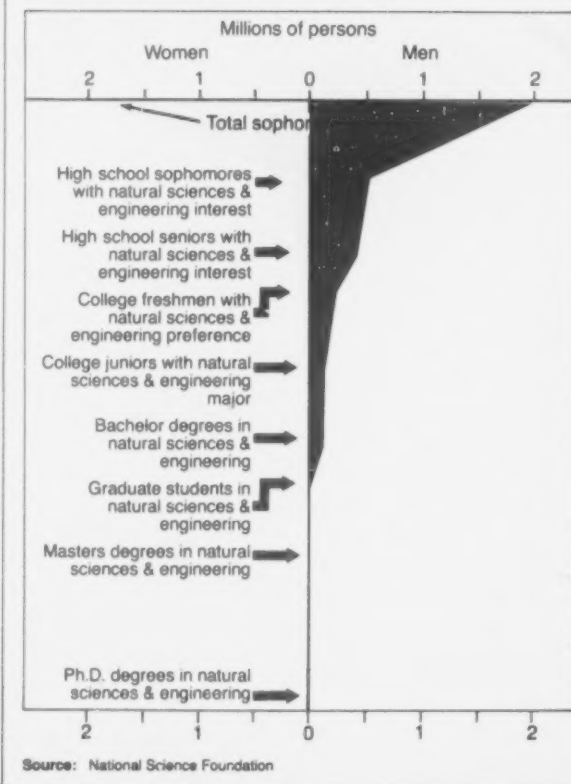
Conner notes the most common reason students are saying they would like to switch to another major is that chemistry is too hard. They're not prepared for it. They're not able to handle the math and the physics. "A lot of them didn't know they were going to have to take physics," Conner explains. "They had a good time in high school; they had a high-school chemistry teacher they liked; they had fun in high-school chemistry lab; but they didn't have to know any math and they didn't have to know any physics."

Another big problem, as Conner sees it, is a common attitude of students that is strongly supported by parents. The attitude is that they are in college not to get an education but to prepare for a career. They want that career to pay as much as possible, but they'll settle for less money if they don't have to work as hard.

Not just difficulty with math and science but experiences with science that can only be described as appalling have been responsible for turning students away from majors in the natural sciences. A vivid impression of these experiences emerges from condensations of student "science autobiographies" collected by Nancy Brickhouse, a professor at the University of Delaware in the department of educational development.

"I found thoughts of science and dissecting animals and microscopes and complex formulas intimidating," writes one student. "In high school, I began to dislike science, and I found it to be very frustrating. In elementary school, I liked science. However, in high school, my opinions about science . . . began to change. I found the material—particularly what we were learning in chemistry—to be very difficult and frustrating. I also had a couple of teachers who completely turned me off to science. They may have known the material, but they just were not very good at teaching it. I can remember sitting at my dining room table with my Mom trying to do chemistry problems. I remember just cry-

### The science pipeline: ...and women represent another



ing because I had no idea how to do them, and my teacher felt as though we should be able to do them even though she hadn't taught us. It was a horrible year in chemistry for me."

Another student writes: "I did not choose a science-related career because I never did well in science. As a younger child I remember doing science experiments in class. And I did like them a lot, but I guess it was in high school that I started to dislike science. I never failed or got a D, but it was something that got me flustered and confused. In high school, I took biology, chemistry, geology, and physics. I liked biology; my teacher knew I had a little difficulty with science and he helped me a lot. On the other hand, I really disliked chemistry. I could study four hours straight and still find some way to make a mistake. My teacher was another reason I did not like this class. He was very boring, and he never clearly explained things. In college, it all changed. When I took biology, I hated it. There were so many different concepts and ideas that all I could do was to be confused."

Plaintively, a third student writes: "My experiences with science have been like a roller coaster. Everything started out well enough. I went to high school with a very optimistic outlook about science. I first encountered [my teacher] for biology who awarded me my first D, and to top it off he told me I deserved it because I was immature. Such a lovely man. Next ego basher was [my chemistry teacher]. She was retiring after that year. We all felt cheated. Why couldn't she have just retired the year before? During the first week of school she said that she didn't need us, but we needed her to pass. She said she would fail people and didn't think twice. She actually found joy in it. So I became her prophecy and received my first and only failing grade. Such a lovely woman. Onward to [my physics teacher]. College science courses weren't nearly as harsh since they brought an upswing on the roller coaster. I did not choose a science-related career because science has been rather traumatic through most of my older years, and why dedicate my life to squeezing the wound?"

There are many more examples. Commenting on them, George M. Bodner, professor of chemical education at Purdue University, notes that the vast majority of the students had taken biology, chemistry, and frequently physics at the high school level—all the courses that they would have needed at that level to become science majors. But they didn't. On the basis of these observations, Bodner has developed nine assertions, or generalizations.

First, some students are driven away from science in the elementary grades because it is obviously less important than the really important subjects like reading, mathematics, language arts, or the social sciences.

"If it were important," Bodner says, "we would be doing it. We wouldn't do it at the end of the day. We wouldn't be doing it when we run out of useful things to do." If you don't have teachers at the elementary level who value doing science, he adds, if you don't have people at the elementary level who know how to do science, you're going to lose some of your potential majors at that point.

Bodner next asserts students are driven away from science in middle school when it is taught as a product rather than being presented as a process.

If science is nothing but a regurgitation of facts, Bodner says, it is boring. "If it is a science, a process, where you do observation, where you do analysis, where you have to think, where you have to predict, then the students enjoy it—sometimes even the teacher enjoys it—and some of them go on."

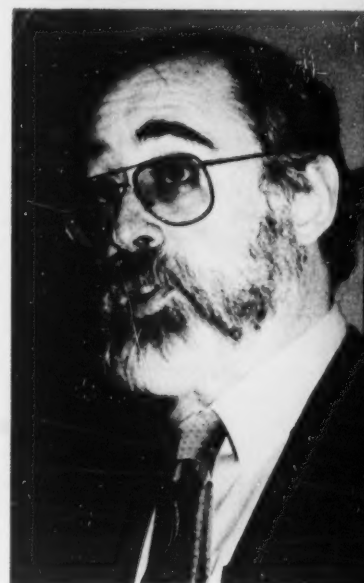
His third assertion is that students are driven away from science when the discipline is taught as knowledge without understanding.

As a fourth point, Bodner says students are driven away from science when the only alternative seems to be memorization of facts (which are boring) and equations (which are meaningless).

Fifth, Bodner says students are driven away from science when they are confused or frustrated. It's possible to keep very high standards in a course, Bodner maintains. "Indeed," he says, "that may be what one of our functions in life is. But that doesn't necessarily mean that students need to walk away from the course with the feeling that they can never understand, that they can never manage, that they can never be successful in science, that it takes a special kind of individual to be a scientist."

Bodner's sixth assertion is that students are driven away from science by strict adherence to rules; when creativity is actively discouraged.

Bodner tells a story. "I have a colleague," he relates, "who had a young son who took a course. He came home from a middle school science course in tears because the teacher had failed him on an assignment. And he failed him on the assignment because the assignment was a graph. And what the student plotted





Crosby (clockwise from above), Bodner, Conner, and Lagowski decried state of science curricula during recent ACS national meeting

on the y axis has to go on the x axis, and if you don't reverse the axes, it's obviously wrong. So if you don't produce the axes like it was in the textbook, you get zero credit."

Bodner's seventh point is that students are driven away from science when it has no relevance to their lives.

His eighth assertion is that students are driven away from science by teachers who cannot explain what they know.

Right now, Bodner says, chemistry and physics majors are being graduated to be teachers who don't do well in the classroom. They want to do a good job, he says, but they are not being armed with the skills needed to do a good job. They are getting most of the content knowledge that they could hold at the time they graduate. But they are being provided with virtually nothing in the way of pedagogical content knowledge, he says.

For his final assertion, Bodner looks to Latin to explain: *De gustibus non est disputandum*. Basically, Bodner quips, this means that in spite of everything, there is no disputing taste. "Some people will still, in spite of everything

we do, decide to become scientists. If we could find some way of gently increasing that, then the field would probably be a little bit healthier."

Gentle is not the approach some would use toward introductory chemistry. Indeed, the early college experience is one that has many chemical educators issuing impassioned calls for reform and revitalization in words that sound like revolution.

"I think we need to revitalize the undergraduate program. And I don't think we can tinker with it," says Glenn A. Crosby, a chemistry professor at Washington State University, Pullman. "I think we should dynamite it and start over."

For many reformers, the undergraduate program is

the focus of numerous issues. There is the issue of appropriate attitudes toward majors and nonmajors, issues relating to curriculum and to laboratory facilities, the issue of the proper role for teaching versus research.

"We've got to start looking at the nonmajors," Crosby states. "God must have loved the nonmajors," he says, "he made so many of them." Yet, he adds, chemical educators have forgotten the nonmajors. "We're going to have to turn our attention to the education of the entire populace and not just [those] that might get replicated in our own image."

Crosby sees a danger in emphasizing chemistry in particular and science in general as a vocation rather than as an education. Noting that in his opinion, chemistry is a new liberal art, Crosby says, "We've been indicating that if you study chemistry, you might get a good job. And that may be true. But I think that's ancillary to the fact that we should be teaching chemistry for what it is: something that without the knowledge of it, one cannot live in psychological comfort in the last half of the 20th century and certainly not in the 21st."

Joseph J. Lagowski, a chemistry professor at the University of Texas, Austin, also believes a disservice has been paid nonchemistry majors, though they may have indicated an interest in science, and that the whole ambiance is bad for attracting chemistry majors. This, he says, has drastically affected retention rates for aspiring chemistry majors. He describes the ambiance as one where students find that if they are going to be seriously considered as junior colleagues in the discipline, they have to come already committed to the discipline.

In many large institutions, Lagowski says, chemistry majors are essentially sequestered and expected to take an honors course or the equivalent. The rest of the science majors go into a different course. The chemistry course for science majors generally doesn't get the resources that the other courses get. Classes are generally large. The resources with regard to the laboratory component are generally poor. And very often the faculty members are "less than enchanted" in trying to teach these students.

Says Lagowski, "We're essentially saying to a very large number of people who fundamentally have an initial perceived interest in the physical sciences, 'No, no, we're not going to take you seriously unless you come to us already annointed as a chemistry major.'"

If one looks at many of the things done in chemistry, Lagowski says, "we do it as a service to other disciplines. And we don't do it well. And then we are unhappy because our discipline is going down the tubes."

"Why do we study chemistry?" asks Oregon State University chemistry professor Stephen J. Hawkes. It would be nice, he says, to believe that students are being made to study chemistry so that they can make good decisions. "But, you know," he says, "to come right down to it, I haven't been able to think of many decisions that a person with one year of chemistry would be able to make."

There is the matter of communications. "I have students," says Corvallis-based Hawkes, "who have told me as they dropped my course, 'If ever I need any chemistry done, I'll hire a chemist.' And my reply is,

'No you won't. Because you don't know enough chemistry to know that you need a chemist.' I think we need to teach them enough chemistry so that they know that there are problems that the chemist can solve."

And they are not common problems about the pH of 0.1M formic acid, Hawkes adds. Hawkes, like many chemical educators, is concerned about the irrelevancy of the introductory chemistry curriculum to many students. Having given the matter some thought, he says, he has come to a conclusion: Chemistry is boring. "I have been getting around to wondering," he adds, "why anybody ought to find it interesting."

Hawkes describes an experience he had recently when, in preparing for a chemical meeting, he asked some chemists if there were comments they would like to make about general chemistry. One of them reacted explosively, Hawkes relates. "He said, 'Yes! I have two kids in high school who are taking high-school chemistry, and what they are teaching them has nothing to do with what I do for a living.'"

What do chemists do? Hawkes asks. Chemists, he says, design things, like cracking processes for petroleum; they formulate things, like water repellents; they analyze things, like their competitors' products; they synthesize things, like lightweight plastics; they isolate things, like bromine from seawater; they predict things, like how long it takes for gasoline to be carried away once it gets into the atmosphere; they prevent things, like corrosion.

"I have a feeling," Hawkes says, "that the reason that everybody says you've got to have a lab in freshmen chemistry is that the chemistry that we teach them is so irrelevant to anything in their experience that you've got to have them in the lab so they see something concrete. If we could only talk about the chemistry of real life, they wouldn't need to see it in the laboratory; they could see it walking down the street."

It's all very well to say what you put into general chemistry, Hawkes notes. Perhaps more to the point is what should be left out. The first question that should be asked about anything that students have to learn is why they should know that. "I think if we were to ask that question a lot more often," Hawkes says, "we would make a chemistry course which was a lot more interesting."

Crosby would certainly agree. In his appeal for an invigoration of undergraduate chemistry, he is calling for a look at the entire content of what is taught. He notes that students are very impressionable, soaking up information from newspapers, television, and elsewhere. "They soak up the acid rain problem," Crosby says. "They don't know what it is. They know there is one. They hear about the ozone hole. They hear about recycling. They hear about the rain forests dis-

appearing. And they don't really understand it. And they want to learn something about those things. And we cleverly manage not to teach them anything about it in our courses."

Likewise, Crosby continues, "they're interested in their own bodies. They're interested in drugs. They're interested in AIDS. They're interested in genetic engineering. They're interested in what photosynthesis is. And we cleverly in our beginning courses avoid mentioning anything like that because it's too damned interesting."

The result, Crosby says, is that students are turning away because they don't really see anything relevant. "It is relevant. And we know it's relevant. But they don't know it's relevant. We're requiring them to know the bridges to their ordinary lives, and we're not building them for them."

### Lab operations also under the microscope

Curriculum isn't the only target of critics of the system. Laboratories come under the gun as well. The poor physical environment of the laboratories is a problem, says Lagowski. The problem, he points out, is how to do the requisite laboratory work for, say, 22 cents per student. "You know," he says, "we've let ourselves get into that position. We have let the nebulous 'they,' who in some instances is 'us,' get us into that position."

As a result, Lagowski says, "the place where students will do our science is generally a shambles—a physical shambles, an intellectual shambles, a shambles in general. And it's not surprising that a student can't really figure out what the point of anything is."

"Laboratories are stultifying," declares Crosby. "They're uninteresting. There's too much emphasis on principles and not enough on colors and sounds and explosions and smells."

There's not enough there that can stimulate the imagination of students, Crosby maintains. "Maybe for



Carbide chairman Kennedy chats with (from left) staff members Anthony and Linda Vecere and Technicians Today editor Elizabeth Crawford-Harrison

us those principles are very interesting. But for a student who is just going into the field, that person doesn't have enough phenomena to hold onto to be able to hang the principles on."

As an approach to revitalizing the way general chemistry is taught, Lagowski appeals for creation of an ambiance where "we will essentially empower faculty to help students learn, and empower students to learn." It's an ambiance, Lagowski says, where learning will become more active. That means, he says, lectures should be fewer. Books should be thinner. Examinations will be different. The curriculum will become more laboratory-oriented. ("That's the heart of our science. . . . Chemists make things.") And laboratories will be more flexible.

"That's the ambiance," says Lagowski. "That's the ambiance in which a renaissance can occur. And for those who have a historical perspective, that is the ambiance from which we came. And somehow we have arranged for ourselves—administratively, resource-wise, whatever—to go away from a very successful ambiance. And I think it's just wrong. And we somehow have got to figure out how to get back to the future."

More than just introductory courses in chemistry are currently in the thoughts of chemical educators. For example, California Institute of Technology chemistry professor Harry B. Gray notes chemistry is in a dynamic period, a period of tremendous change. The basic paradigm of chemistry has changed, he says, and educators are faced with responding to that somehow in chemistry education and chemistry teaching.

As Gray sees it, the old paradigm was based on the traditional subdisciplines—physical chemistry, inorganic chemistry, organic chemistry, analytical chemistry, and the like. The four operations that have now taken over, he says, are chemical synthesis, chemical biology, theoretical chemistry, and experimental chemical physics.

"These are the four areas that I see people working in today," Gray says. "And I think that the educational establishment somehow has got to respond to what's going on in chemistry, so that what's being taught to freshmen and sophomores and juniors—majors and nonmajors alike—will reflect what's really going on now."

What's at stake, Gray says, is whether the words chemistry and chemical will remain. "Chemistry will be with us forever, and chemicals will be with us forever," he says. But what is at stake "is whether the chemistry group—our group—will in fact call the shots in education." The chemical community, he observes, is now engaged in an interaction with two other communities: materials and engineering on the one hand, and biology on the other. "The question now," he says, "is will the materials and engineering community be teaching our subject or will we; will the biology community be teaching our subject or will we. That's what we have to address."

Gray notes that change is going to be very difficult. But if he had his way, he says, he would redesign the whole curriculum now, starting with chemical synthesis as the first course, and concentrate on hands-on



**Hawkes (left) and Gray call for curriculum to reflect what chemists do in today's world**

work in the first year. "I'm talking about a new level of hands-on work in the first year," he says, "built around synthesis and the structure and characterization and analysis of the molecules and other substances."

Beyond the level of concern over curriculum there is the issue of teaching versus research, the interaction of which is of increasing concern to many. There needs to be a balance between teaching and research, Crosby says. It's been badly out of balance for a long time, he contends, because of the reward system.

"The reward system is like the weather," Crosby says. "Everybody talks about it but no one does anything about it."

The result, he maintains, is that students perceive that university professors are haggard and worried about their careers. "They are being asked to be entrepreneurs. They are being asked to get large amounts of money to support overhead. They are being asked to write grants successfully. They are being asked to finance their own salaries. They are being asked to do all these things. And then they ask the question, 'If I'm going to go through all this, why don't I just go out into industry and make more money?'"

Crosby adds many professors are thus portraying role models of the wrong type. The students see it and react to it. "They are," he says, "much more impressionable than we give them credit for. And they're wiser."

Crosby's remarks echo those of Stanford University president Donald Kennedy. In an address to the Stanford Academic Council in April, Kennedy too called for a better balance between teaching and research.

"The joint product character of our enterprise has long been a source of strength to us," Kennedy said. "Teaching and research are both important, but the relative weight has shifted over time, as the relatively new term 'research university' suggests. It is time for us to reaffirm that education—that is, teaching in all its

## Sigma Xi: an interdisciplinary view of undergraduate science education

When Sigma Xi, the scientific research society, convened an interdisciplinary National Advisory Group of 35 individuals at Wingspread in Racine, Wis., a year ago, it presented the group with two charges: Explore the nature and quality of undergraduate education in science, mathematics, and engineering; and identify the significant topics and issues that should be addressed in charting policy for undergraduate education in science, mathematics, and engineering.

The Wingspread meeting brought together representatives from the sciences, mathematics, engineering, medicine, economics, communications, sociology, psychology, philosophy, education, university administration, government, scientific societies, and other areas. Anna J. Harrison, professor emeritus of chemistry at Mount Holyoke College, South Hadley, Mass., and a former president of the American Chemical Society, chaired the meeting. Describing it at the ACS national meeting in Boston, she noted a "unanimity in discussion that I had not anticipated. In fact, the unanimity was so high, it was somewhat frightening."

An interdisciplinary group is important, Harrison says, because a group of that sort raises generic issues, issues that are common to all the sciences, not just issues that might have been thought specific to chemistry. That sort of group, she adds, also highlights the synergism among science, mathematics, and engineering.

That synergism is important, Harrison stresses. It is important, she says, that students who will not become professional scientists but will be that great mass of the public "understand that it is

the whole group that makes the advances, not just chemistry or not just physics or something else."

The group first agreed upon a statement of the missions of undergraduate education. The reason for a mission statement, Harrison explains, was that if the group intended to explore the nature and quality of undergraduate education, it was necessary to have agreement on what that education was supposed to accomplish. The group agreed that departments of science, mathematics, and engineering have four missions that include encouraging and enabling undergraduate students:

- To pursue careers in science, mathematics, engineering, and related endeavors; careers in school (kindergarten through 12th grade) science and mathematics education; and careers in scientific and technological aspects of law, mass communications, and management.
- To discover the nature of science, mathematics, and engineering.
- To discover the aesthetic and human dimensions of science, mathematics, engineering, and technology (the order and beauty of many natural systems and many products of technology; the ingenuity of the human mind in creating models to rationalize the properties of systems and in creating technological options for the production of goods and services and the resolution of societal issues.)
- To become informed participants in the democratic processes through which value-laden issues involving science, mathematics, engineering, and technology are resolved.

Harrison notes that all the personnel pipeline concerns are focused on the first part of the first mission. As for the second mission, she says it may seem a little queer to include it, but she also says she sometimes wonders if some graduates in chemistry know what the nature of science is—that is, not a body of knowledge but a process of investigation.

According to the advisory group in its report, evidence is mounting that undergraduate education in science, mathematics, and engineering is not fulfilling its missions. For example, it notes, "More than 50% of freshmen intending to major in science, mathematics, or engineering fail to complete bachelor's degree programs in these fields, to say nothing of the many future teachers, communicators, managers, lawyers, political activists, public officials, and socially concerned citizens who are rendered permanently allergic to these fields by unfortunate experiences in introductory courses." The group says the crisis applies both to science, math, and engineering majors and to students majoring in other fields.

The advisory group identified seven fundamental topics that it believes need to be addressed. Harrison notes that topic seven—promises and special needs of traditionally underrepresented groups in science, mathematics, and engineering—is a separate issue. The other six, in order of significance, are:

- Quality of instruction. "Undergraduate education," the group says, "is trapped in an infrastructure that rewards those who devote their resources to research and denies those same rewards

forms—is the primary task and that our society will judge us in the long run on how well we do it."

Perhaps it remains for Alice J. Cunningham, chemistry professor at Agnes Scott College, Decatur, Ga., and a member of ACS's Committee on Professional Training, to put a final gloss on the problems of undergraduate chemical education. Noting in another context that funding isn't the only problem in bringing about the changes being discussed, she also points out that when she was a student, there was a 180-day school year. Now, she says, the academic calendar has been pared. Semesters have been cut. "Do your mathematics," she says, "and you will find that we have lost six months of instructional time in a bachelor's program."

This group of concerns addresses questions raised by the issues of the science personnel pipeline and the place of chemistry in higher education. But as such they are only a part—though an integral one—of a much more extensive concern about science education and about science literacy of the public in general. And it is this broader concern that has in recent years generated so much of the report writing and, indeed, a great deal of activity.

At the ACS meeting, Shakhshiri provided a philosophical underpinning for the concerns involving science education in general. "Our literacy in science and mathematics," he states, "reflects our values as a society—what we care about, what we believe in, how we



**Harrison: values key part of policy-making**

to those who devote a significant portion of their resources to fulfilling the mission of undergraduate programs—to encourage and enable undergraduate students to achieve. The practices of many segments of society (including the research community, college and university administrations, state and federal governments and their agencies, and private foundations that fund research) have created and reinforced the value system that produced and sustains this dichotomy."

- **Quality of curriculum.** "The student perception of the undergraduate curriculum in science, mathematics, and engineering and the faculty perception of that same curriculum are by no means congruent," the advisory group says. "Many freshmen view entry-level courses in science, mathematics, and engineering as inaccessible—or if accessible, unre-

warding to them." The group identified entry-level courses in science, mathematics, and engineering as "water-sheds" that determine both the place of science, mathematics, and engineering in the lives of those who go to college, and the vitality of undergraduate programs in these disciplines at colleges and universities.

- **Quality of the human environment.** "Large classes," the group says, "impose student/faculty ratios that often make the faculty inaccessible to all but a few students and, at best, students view the human environment as impersonal. The common practice of using entry-level courses as barriers to protect more advanced courses from all except the most able and the most committed still persists and, at worst, students view these classroom environments as destructive and hostile."

- **Quality of the physical environment.** Recognizing the value of adequate libraries, laboratory facilities, and instrumentation, the group focused its attention on the aspects of the experience within that physical environment that it says are truly educational to students. High value was placed upon the student having hands-on experience with the investigation of phenomena. "Through this experience," the group says, "the student has experience with critical thinking, planning, analysis, and synthesis, and the opportunity to discover the integrity of data, the uncertainty of measurements and, through these, the development of understanding of the powers and limitations of science and engineering."

- **Accessibility and flexibility of curricula essential for student mobility.** The

faculty, the group says, may view an undergraduate major as a carefully sequenced program of courses. To the student, a tightly sequenced major in a discipline may be perceived as a one-way express road with an entrance ramp in the freshman year and an exit ramp at the completion of the major in the senior year—no interchanges along the way. "The student who wants to participate in charting his or her undergraduate education on the basis of experience and developing interests needs a map with interchanges to major sequences in other disciplines," the group adds. "If interchanges between disciplines do not exist, attention should be given to creating them."

- **Attitudes and perceptions of students, faculties, administrations, and the public.** The group notes that in the presentation of the preceding five significant topics, issues related to attitudes and perceptions have arisen repeatedly. "In charting policy for undergraduate education in science, mathematics, and engineering," it says, "bringing about changes in attitudes and perceptions must be a part of any effective policy."

Harrison says if she could change the list now, she would add "values" to the last topic to make it "attitudes, perceptions, and values," and she would move the topic to the top of the list. Much of the talk concerning education at the ACS meeting, she noted, was talk about attitudes, perceptions, and values, which she found promising. A few years ago, she says, these words couldn't be used. Anyone using these words would have been laughed out of the room. "You just couldn't discuss it."

treat each other, and how we treat our environment." He stresses that by science literacy, he means literacy for all people. "If you care about the quality of life in our society," he says, "then you will care about joining forces and seeing to it that all segments of our society are enabled to fulfill their human potential."

Shakhashiri believes those in the science-rich sector of society owe something to the science-poor sector of society. By science-rich sector he means colleges and universities, parts of industry, and the national laboratories; by science-poor sector, everyone else.

It is fairly well understood, and even agreed to, Shakhashiri says, that the science education battle is lost not in the sophomore year in high school but earlier. And

that's why NSF has been heavily focusing on middle school and elementary school levels.

"However," Shakhashiri insists, "that's where we don't have chemistry courses, that's where the disciplinary demarcation lines disappear, and that's where we, as chemists and chemical engineers, have got to show up on that playing field and see to it that there is quality education at the middle school level and the elementary school level in science."

Shakhashiri admits he is often accused of preaching to the choir. If so, he says, it's because "I want the choir to sing. And I want the choir to sing out loud and in harmony." He even supplies some lyrics, hurling challenges to various sections.

For example, to ACS and members of ACS, he urges: Expand the efforts of the education division and strengthen the operations of the division of chemical education; widely broaden national and local section programs ranging from National Chemistry Week to recognition of high school chemistry teachers; work with middle school and elementary school teachers; help lead national curriculum developments at the undergraduate level; take the "Procter & Gamble" approach (five or six high-quality soaps for the market to choose from) to curriculum and put out five or six alternatives in the curriculum area so that school systems and colleges and universities can choose from among them; support and participate in the AAAS Project 2061 and a National Science Teachers Association (NSTA) companion project called Scope and Sequence; continue to inform Congress about national needs in research and in education; update the ACS's 1984 Yankwich Report ("Tomorrow: The Report of the Task Force for the Study of Chemistry Education in the United States"); and help to influence other organizations "to see to it that the intellectual prowess of this nation devotes a fraction of its effort to deal with those science education issues at all educational levels."

To industry, he challenges: Expand support for major reform efforts in science education, not only supporting Presidential Young Investigators awardees but also undergraduate faculty and high school teachers; participate in forming alliances and coalitions with school systems and with institutions of higher education, seeing to it that there are standards in the school systems and that those standards are achieved, and "seeing to it that no school in the U.S. can use any excuse for not offering a chemistry course and not offering a chemistry course with a laboratory component;" help infuse ideas into other business organizations, such as the local Chamber of Commerce, so they can continue the interest they now have in solving the problems of science education; continue to influence national policies in science and science education; and be responsible for informing the public about chemistry, about chemicals, their benefits, their safe handling, and their potential hazards.

To colleges and universities: Be ready and prepared to take on the responsibility of a huge influx of funds that "there is little doubt in my mind" will be coming from the federal government and from the business sector in the next five to 10 years to colleges and universities to address the problems in science education at the undergraduate and precollegiate levels; address research versus teaching issues to achieve an appropriate balance; stop, immediately, taking pride in weeding out so many students at the freshman and sophomore years ("We are in the talent development business; we are not in the business of weeding out students"); and look at the outcome of the educational process, asking what it means to be the holder of a bachelor's degree from a given institution ("If concern about curriculum is not a primary concern of the faculty, I don't know who else is going to be concerned about it").

To the federal government and, specifically, NSF: Develop a national strategy with a set of goals and stan-

dards, goals with regard to student achievement, teacher qualifications, the environment for learning, and the quality of the curriculum.

As to the strategic role of NSF in all of this, Shakhshiri says, it adds up to science literacy for all students. "We want the best preparation for careers in science and in teaching science," he says. "We want to increase representation. We support experimentation. We're interested in generating change—fundamental, comprehensive, systemic change, not incremental change. Incremental change is not going to work. When you have incremental change the sum of the parts does not add up to the whole. We want to assist in the implementation, and that's what the NSF funds are for, to assist in the implementation and see to it that we have a national major strategic effort that can solve the problems that face us."

### Goals for turn-of-the-century set by governors

Many of the efforts called for by Shakhshiri, or parts of them, are, of course, already under way. The federal effort, for example, received a big boost from President Bush and the state governors last October. At an education summit held in Charlottesville, Va., the President and governors declared, "The time has come, for the first time in U.S. history, to establish national performance goals, goals that will make us internationally competitive." That said, they enunciated six national education goals:

- By the year 2000, all children in America will start school ready to learn.
- By the year 2000, the high school graduation rate will increase to at least 90%.
- By the year 2000, American students will leave grades four, eight, and 12 having demonstrated competency in challenging subject matter including English, mathematics, science, history, and geography; and every school in America will ensure that all students learn to use their minds well, so they may be prepared for responsible citizenship, further learning, and productive employment in our modern economy.
- By the year 2000, U.S. students will be first in the world in science and mathematics achievement.
- By the year 2000, every adult American will be literate and will possess the knowledge and skills necessary to compete in a global economy and exercise the rights and responsibilities of citizenship.
- By the year 2000, every school in America will be free of drugs and violence and will offer a disciplined environment conducive to learning.

It is these goals that are now the engine driving federal government efforts in science education. They underlie, for example, the recent program announcements of NSF's statewide systemic initiatives and of the Department of Energy's science education initiatives.

Some people snicker at the goal of making the U.S. first in the world in science and math by the year 2000, Shakhshiri notes. But, he points out, it's a remarkable accomplishment for the President and governors to agree on the goals. "What we have to do," he says, "is join in making a very serious attempt to achieve that goal. Otherwise, it will become an empty goal." Indus-



*Samuel (left): middle school is last chance to hook child's curiosity of natural world. Gardner: must not lose chemistry during early school years*

try is one group that is taking the challenge seriously. Numerous specific activities sponsored by individual companies are adding up to a ferment of activity in the industrial world. But the business sector is also addressing science education issues more generically, as business.

Keynoting an ACS Corporation Associates symposium in Boston on the topic of industrial initiatives in precollege science education, Union Carbide chairman and chief executive officer Robert D. Kennedy outlined the approach business is taking. President Bush, he notes, met with business leaders last fall the day before the governors' conference and challenged them to become involved in a truly common effort for education reform. The result, Kennedy says, is that a separate section of the Business Roundtable organization has been established for each state. Kennedy heads the Connecticut section.

The Connecticut section, which met just recently, has set three goals. The first goal, at the state level, is to establish a vision of what the educational system should be. It involves, Kennedy says, comparing the situation that exists now with what it should be. It involves defining what a person should know who's in grade eight, 10, and 12—what constitutes an adequately educated person. And the goal must be defined by global standards, Kennedy says, because American students are competing with students from all over the world.

The second goal is for the business group to push its point of view on policy issues. For example, Kennedy says, of the 20 cities in the U.S. with the most severe inner-city education problems, three of them are in Connecticut. So one of the policy issues being tackled,

he says, is determining what kind of resources are needed in the worst places, so that students there can compete with students in the best places.

The third goal is to sound the alarm generally. Change isn't going to happen, Kennedy says, unless people are really dissatisfied with the situation that exists. They have to be told what's wrong, why it's wrong, and what the implications are. Then, he adds, business must develop partnerships with parents and students, and with educators and teachers and other people who want to improve education.

Kennedy doesn't mince words in describing the situation as he sees it: "We have an education crisis of epic proportions in this country. It's been building for 40 years. It's not going to be solved in anything less than 10. And most of our citizens aren't aware of it, concerned about it, both or either."

Strong justification for Kennedy's views comes from the Union Carbide task force study made last year. Kennedy had appointed the task force and had charged it with defining the issues in education and the corporation's role in their solution. The resulting report, he says, "has become a blueprint for our corporate involvement in trying to build a world-class education system." The company, he says, is committing years of personal effort and corporate resources because it doesn't believe the problem can be solved with Band-Aid solutions.

Business people don't have all the solutions about what to do, Kennedy admits. But, he argues, they do have experience in such areas as setting goals and measuring performance. And they do have some idea about requirements for the jobs of the future.

Kennedy has found a lot of people are already becoming nervous about business getting too involved in education. He noted, for example, at a recent education conference parents and school boards expressed the fear that the only reason business is interested in education is because it wants a quality work force—that business looks on education as a trade school.

"Wrong," says Kennedy. "We've got to turn out world-class educated kids by grade 12 just so they can be qualified citizens—not fodder for business—just qualified citizens."

Kennedy thinks that outcomes, results, are a very appropriate role for business executives, for parents, for citizens. "We have to measure what the product is. And measure it against the competition."

In education, Kennedy explains, the product is the student. The consumer is the parent. And the consumer is the taxpayers who foot the bill for public educa-

## Union Carbide task force views business as a catalyst for change in education

Many companies have programs of one sort or another focused on education in general or science education in particular, and some of the programs are fairly extensive. However, Union Carbide has begun what may be one of the more involved efforts.

In December 1988, Carbide chairman and chief executive officer Robert D. Kennedy established a corporate task force on education to study elementary and secondary education and to report to him on an appropriate role for Carbide in addressing that issue. In the report that resulted last year, the task force notes that although it recognizes learning is valued in its own right, its report focuses on how well the education system is meeting the economic interests of the country and the company.

Not very well at all is the answer found by the task force. The task force's report sets the stage with a statement that is an adaptation from "Workforce 2000," a recent Hudson Institute study on work and workers of the 21st century: "Our vision: Every child who reaches the age of 17 can read sophisticated materials, write clearly, speak articulately, and solve complex problems requiring algebra and statistics. Unconstrained by a shortage of competent, well-educated workers, American industry is able to expand and develop as rapidly as world markets allow. Boosted by the productivity of a well-qualified work force, U.S.-

based companies reassert historic American leadership in old and new industries, and American workers enjoy the rising standards of living they enjoyed in the 1950s and 1960s."

Concludes the task force: "We will not fulfill this vision without fundamental changes in our elementary and secondary education systems."

In pursuing its charge, the task force researched the issues for some six months, reviewing a wide variety of publications and documentaries and conducting numerous in-depth interviews with educators and education leaders. In April 1989, it hosted a forum at the Union Carbide Center in Danbury, Conn., on emerging education issues. Fifteen education and business leaders were presenters and panelists for the forum, which drew together Union Carbide representatives from key community locations, local school superintendents, and others from Carbide communities, as well as the corporate task force members.

Although the task force's conclusions about the poor state of education are similar to those of numerous other studies, its deliberations brought a somewhat different perspective to bear on the education problem. As a result of its research, the task force says it determined there is a critical problem and it is much misunderstood. The problem, it says, is that schools have remained the same,

while the economy and society have changed and the country's educational needs have become greater. The result is a relative decline in school performance.

The U.S. school system, the task force explains, was designed for an agricultural economy, and the structure hasn't changed for more than 100 years. At that time, it wasn't necessary or even desirable to highly educate everyone. But that is the goal today, and the outmoded system that exists is incapable of meeting modern needs.

The task force notes four trends that are converging toward trouble: Population growth rate is declining, and the number of 16- to 22-year-olds entering the work force is shrinking; jobs require high levels of knowledge and skills; student achievement hasn't increased significantly and by some indicators has sharply declined over the past 20 years; and minority students, who are least well served by the school system, are the fastest growing segment of the population.

A larger portion of students must be educated better if the country's labor needs are to be met, the task force says. This calls for increasing student achievement levels across the board. But inherent limitations in the school system prevent it from living up to the challenge.

"Without improvements," says the task force, "we have, at best, an un-

tion. And the consumer is U.S. society in general. "There are lots of consumers of education," he says, "and the product they're all getting is not good enough."

The problem, in Kennedy's view, doesn't lie with the teachers. It is the educational system itself that's at fault, he charges. In that regard, he quotes Albert Shanker, president of the American Federation of Teachers: "If I worked in an office that was organized the way secondary schools are, I'd be given a desk, and there would be 25 or more other workers sitting around me doing the same work. I could never talk to them. There would be a boss to tell me what to do. Every 50 minutes a bell would ring, and I'd go to another room with 25 different people to do a totally different kind of work—with a new boss. I'd be encouraged to make mistakes instead of checking my work with someone sitting next to me—because that would be cheating. And I'd be humiliated by having my mistakes called to the attention of the entire office. . . . It's not surprising

that no office in the world is organized the way our schools are."

Kennedy calls for nothing short of revolutionary change, complete restructuring of the system, because everything is interrelated. "The kinds of teachers we get," he says, "are related to the kind of reward structure and professional environment we provide for teaching. That's related to the way we allocate resources and responsibilities at the schools. That's related to the way we finance and structure education. That's related to the politics of education. And all that's related to the kind of motivation students receive from their peers and from their parents. And whether inner city kids are even prepared at age five or six to start into the system."

So, he concludes, "If we want to do it right, we have to do it all. What we need is nothing less than revolutionary changes in the way we educate our children."

Kentucky is an example of a state taking this approach, Kennedy says. Last month, he points out, the

dereducated population which keeps this nation from realizing its highest economic potential. More likely, we have a threat to our international competitiveness and to our standard of living." The task force called its report "Undereducated, Uncompetitive U.S.A."

The task force points out that with some 16,000 independent school bureaucracies in the nation with about a century of experience invested in the status quo, the system is resistant to change, and the momentum cannot come from inside. Educators with vision, the task force says, are asking for help from without.

This is an appropriate and critical role for business to play, the task force says. More than \$180 billion is spent annually on education. Business, it argues, has a major investment in the system, through tax dollars, and a major stake in the output. Business therefore has an obligation to make sure the system performs optimally.

The task force recommends Union Carbide support and initiate programs designed to bring down the barriers to school reform and to stimulate change. The efforts, it says, should be directed externally, to the general public, and internally, to Carbide employees. It recommends four cornerstones to the efforts:

- A powerful information campaign to change public attitudes toward education. Carbide, says the task force, would take a leadership role in coordinating a massive effort to raise public expecta-

tions similar in scope to the national acquired immune deficiency syndrome and smoking awareness efforts.

- A leadership role in creating a national coalition to establish educational goals. (The task force notes since its report was written, the National Governors Association has taken the lead to establish national goals and that Carbide's activities aimed at educational goals will be coordinated with this effort.) "Education today," says the task force, "is like an industry unclear about its product and, therefore, unable to practice quality control."

- Bold demonstration programs of school reform in two Carbide communities. Union Carbide would sponsor models for major school restructuring, and results would be shared with the nation. Models, the task force says, would be built around principles of teacher autonomy, parental involvement, school-based management, raised expectations for academic performance, clear goals and measures of accountability, and greater "results orientation" rather than "process orientation." There would be a mentor component in which active or retired Carbide volunteers would pair up with "at-risk" students and provide support and encouragement.

- A rigorous and high-profile internal information program directed to raise employee awareness of the education issue and to encourage parents to become more active in their children's schools.

Besides these four "cornerstones,"

the task force identified five additional programs that would complement and round out the involvement. The first of these would be incentive programs for teachers in Carbide communities to become "board certified." Second, the task force envisions political support of legislative changes in key Carbide states and at the national level that favor school reform, such as deregulation of education, alternative routes to teacher certification, and full funding of Head Start programs.

Third, an internal company program would facilitate a mid-career switch to teaching for interested Carbide employees and/or would allow for teaching assignments with simultaneous Carbide responsibilities.

A fourth complementary program would be financial support and promotion of programs to enhance math and science teaching skills at the elementary level in key Carbide communities. And the fifth would be financial support of programs to address potential teacher shortages and to reform teacher preparation programs.

"The issue of public education," the Carbide task force goes on to say, "deserves bold, meaningful action on the part of Union Carbide or none at all. To dabble in the problem will not significantly improve school performance and will not be an efficient use of [Carbide] resources. To make an impact, [Carbide's] commitment to the recommended projects must be long term—not less than 10 years."

General Assembly there enacted what he describes as the most sweeping education package ever conceived by a state legislature. The new system in Kentucky, which will be adopted over a five-year period starting in January, will end state control of local schools. By 1995, the state's 178 school districts must surrender control of local school budgets and educational programs to boards of three teachers, two parents, and the principal. All of Kentucky's current education regulations will be repealed, and the state's Education Department will get out of the regulating business. Its role will be to set learning goals for each subject and grade and to develop ways to assess whether students are meeting them.

### Restructuring the aim, not finding a quick fix

As Kennedy notes, "This is not a quick fix. It's a complete restructuring." Kennedy is not alone in calling for such restructurings. Comprehensive, fundamental, and systemic are words being used more and more to de-

scribe what many see as being needed in approaching the problems not just of education generally but of science education specifically. It is, for example, the concept behind the major new NSF program of statewide systemic initiatives in science, mathematics, and engineering education.

NSF intends its role to be one of providing funds to catalyze a much broader effort. For instance, its solicitation for proposals states that an important consideration in the awarding and continuation of funding will be the degree to which proposals incorporate the use of state, local, and private resources with funds from NSF and other federal sources.

The NSF solicitation notes 10 components that make up what it considers to be covered by the term systemic: organizational structure and decision-making; provision and allocation of resources; recruitment and preparation of those who teach; retention and continuing professional development of teaching and nonteaching personnel; curriculum content and learning goals; de-

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livery of instruction, including the use of educational technology; assessment of student achievement; facilities and equipment; articulation within the system; and accountability systems.

The program will provide awards in the first year to four to eight states for \$1 million to \$2 million, totaling \$5 million to \$10 million to each receiving state over the life of the project, which may be up to five years. Letters of intent to submit proposals are due July 9, with formal proposals due Oct. 15.

Meanwhile, at more local levels, a bewildering array of programs have come into existence. Many companies—chemical and otherwise—have mounted programs designed to stimulate students and provide training and encouragement for teachers. For example, Dow Chemical has worked with NSTA every summer since 1986 to bring high school teachers from school districts across the country to Midland, Mich., for a two-week training workshop in Dow's central research laboratories. The company has also created a program called Touch Tech that reaches some 40,000 students a year to expose them to modern science through seminars for students, videotapes, a chemistry lab for children, and a mentor program.

Du Pont provides another example. It has since 1984 held summer workshops for high school teachers designed to raise the quality of precollege science teaching and foster industry/school partnerships in communities near Du Pont plants. The workshops provide an introduction to polymer technology and biotechnology through lectures, hands-on laboratory experience, and field trips and include an active followup program with graduates to build a continuing relationship.

Still another program variation comes from W. R. Grace & Co. In 1988, the company's Washington Research Center and Atholton High School, both in Columbia, Md., announced the formation of an educational partnership based on the theme of "improving teaching and learning through technology." The goals are to interest students in careers in science by exposing them to real-life scientific research and to use the latest in technology to enhance student learning at all levels. Key elements of the partnership are college scholarships for students pursuing studies in science; a mentoring program; funds provided to the school for computers and audio-visual equipment, including a satellite dish for use in teaching; joint clubs between the school and Grace; and summer employment for two Atholton teachers at the research center as well as an on-going relationship between representatives of both organizations.

These are just a few of the many corporate activities and program variations now multiplying around the U.S. Adding to them are efforts from the government sector such as those of the national laboratories.

Last month, the Department of Energy launched a high-profile effort aimed at precollege math and science education that involves a group of national laboratory initiatives. Besides achieving the direct benefits of the programs, DOE believes that its assortment of laboratories, facilities, and 48,000 scientific and technical personnel give it a unique opportunity to act as a

role model and catalyst for other agencies and organizations. The DOE laboratories and facilities are already heavily active in science education efforts, but the new initiatives broaden the scope. A few of them:

- A program, called Options, from Pacific Northwest Laboratory that connects middle school students and teachers with PNL scientists. The program focus is on schools with a high percentage of Hispanic, Native American, or black students. With staff scientists as mentors, teams of students and teachers meet together on a regular basis.

- A program called the Bay Area Science & Technology Education Collaboration (BASTEC) that involves Lawrence Berkeley Laboratory; Lawrence Livermore National Laboratory; Sandia National Laboratory, Livermore; and Stanford Linear Accelerator Center. The goal of BASTEC is to improve the teaching and learning of mathematics, science, and technology, from kindergarten through the 12th grade, through a collaboration of the Oakland Unified School District with educational and research institutions, community organizations, national laboratories, and businesses.

- A rural teacher training program from Los Alamos National Laboratory and Sandia National Laboratory. It is a teacher enhancement program for middle school teachers in the rural areas of New Mexico, with a large Hispanic population. Included in the program are a summer institute, academic year followup workshops, and classroom visits, with teachers required to establish a chapter of Mathematics Engineering Science Achievement (MESA), a program designed to encourage minority students to pursue careers in science, mathematics, and engineering.

- Science & Mathematics Action for Revitalized Teaching (SMART), a partnership of school systems and national laboratories formed in Tennessee. Designed to enhance education in science and mathematics in Chattanooga and Roane County schools, the partnership includes Oak Ridge Associated Universities, Oak Ridge National Laboratory, Roane State Community College, the Chattanooga public schools, and Roane County schools (including the two systems, Roane County and Harriman). The SMART program includes ORNL-based summer research participation programs and workshops and a summer science camp for students.

- A Science Explorers Program in Chicago that involves Argonne National Laboratory and Fermi National Accelerator Laboratory, the Chicago public schools, and a group of Chicago institutions involved in science education, called the Explorer Partners. Centered on a series of videotaped TV shows created by area TV anchorman Bill Kurtis that features scientists using modern tools to explore the world of modern technology, program activities include laboratory demonstrations, class meetings with staff scientists, and discussions concerning career opportunities. "Mentor groups" of retired scientists will be utilized to provide technical expertise and program coordination.

That so many of the industrial and government programs target the middle school level isn't coincidental. The importance of reaching children in grades five



*Dow researcher works with student in company's Touch Tech program*

through eight, or five through nine, depending on the particular school system, is underscored by Patricia L. Samuel, director of freshman programs at Boston University.

"This is our last chance to hook onto children's innate curiosity about the natural world," Samuel says. "Once they get past the eighth or ninth grade, if they don't like science at that age, they aren't going to like it. So this is really a last-ditch effort."

### **Program aims for better middle school teachers**

Samuel was describing for the Boston ACS meeting a relatively new NSF-funded program at BU in the College of Liberal Arts' school of education called Program for Middle School Science Education. It is an undergraduate program designed to produce better-educated middle school science teachers. The first class of students has been graduated, and another group of seniors is just finishing up student teaching. There are also a couple of masters students who will be finishing soon.

The program is a two-year undergraduate or masters level program, Samuel explains. "An essential ingredient" of the program is that the students are asked to be good enough in science and interested enough in science to be willing to major in it. Most of the students at this point have been biology majors, Samuel says, although currently there are two chemistry majors. In addition to the major, the program includes six education courses plus student teaching.

Samuel explains that faculty from the science departments have been pulled together to design a two-semester interdisciplinary science course for students in the education program. Organized around the idea of products of evolution, the course is team taught—the first semester, for example, starts with astronomy and physics, then moves into some chemistry, followed by geology. The course helps to integrate all the disciplinary pieces.

Such an approach is necessary, Samuel explains, because teaching is not done by discipline in middle school science. It is simply science. "You look out at the world, and there is some phenomenon, and you try to figure out what makes it work."

It is at levels such as middle and elementary that the chemical community must take care to see that chemistry is not lost, warns Marjorie H. Gardner, senior research associate at Lawrence Hall of Science in Berkeley, Calif. For example, she points out that ACS has taken more leadership in the world of science education than any other professional society, at least within the disciplines.

But, she says, although there is a large amount of work going on directed at kindergarten through 12th grade, "we haven't thought

very seriously yet about how we're going to participate in this restructuring of the curriculum and the teaching of chemistry from kindergarten level to the 12th grade level. And I would suggest that that's one of our new initiatives."

Representative of the type of restructuring Gardner is referring to is a new project under way in California known as the 100 Schools project. That's 100 high schools, she says, and each was invited to include a middle school. So that amounts to 200 schools that are engaged in attempting to restructure the science curriculum in a way that would lead to some chemistry being taught every year from grades seven through 12, not in grade 11 alone. The project, she notes, has great implications.

So, too, does a new thrust of NSTA for "science for every year for everyone." The idea is that science would become a part of the core curriculum in the same way that English is taught. It would no longer be an elective.

"This kind of program—science every year—has a lot of merit," Gardner says, "because if it becomes science for everyone every year, and chemistry is well represented, women and minorities are going to be in all those classes. They aren't going to be canceled out at an early age when they can't then follow the options of their interests as they mature. Furthermore," Gardner stresses, "the public at large should develop literacy—practical, useful knowledge of science that they can use in their everyday lives to improve their lives."

So, the assault of the three Rs on science education has begun. Reform, restructuring, and revolution are definitely in the air, but what specific effect they will have isn't yet clear. Nor is the amount of time it will take to solve the problems that exist. As Carbide's Kennedy notes, it's taken 40 years to get to the present situation. As Gassman points out, the solution is at least a two-generation one. □